# Academia Sinica Press Release

# Cosmic Giants Shed New Light on Dark Matter

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An international team of astronomers from Taiwan, the UK and Japan including two scholars from the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) has used the Subaru Telescope to measure the density of dark matter in fifty galaxy clusters and found that its density gradually decreases from the center of these cosmic giants to their diffuse outskirts. This new evidence about the mysterious dark matter that pervades our Universe conforms to the predictions of cold dark matter theory, known as "CDM". The related study was published online in *Astrophysical Journal Letters* on May 17, 2013

Few scientists seriously doubt the existence of dark matter, which researchers discovered almost eighty years ago. Nevertheless, astronomers cannot directly see dark matter in the night sky, and particle physicists have not yet identified a dark matter particle in their experiments. "What is dark matter?" is a big unanswered question facing astronomers and particle physicists, especially because invisible dark matter probably makes up 85% of the mass of the Universe.

The current team, led by ASIAA Postdoctoral Fellow Nobuhiro Okabe and Dr. Graham Smith (University of Birmingham, England), used the Subaru Prime Focus Camera (Suprime-Cam) to investigate the nature of dark matter by measuring its density in fifty galaxy clusters, the most massive objects in the Universe. "A galaxy cluster is like a huge city viewed from above during the night", explained Smith.

"Each bright city light is a galaxy, and the dark areas between the lights that appear to be empty during the night are actually full of dark matter. You can think of the dark matter in a galaxy cluster as being the infrastructure within which the galaxies live." The team wanted to use a large sample of galaxy clusters to find out how the density of dark matter changes from the center of a typical galaxy cluster to its outskirts.

The density of dark matter depends on the properties of the individual dark matter particles, just like the density of everyday materials depends on their components.

CDM, the leading theory about dark matter to date, predicts that dark matter particles only interact with each other and with other matter via the force of gravity; they do not emit or absorb electromagnetic radiation and are difficult if not impossible to see.  Therefore, the team chose to observe dark matter by using gravitational lensing, which detects its presence through its gravitational interactions with ordinary matter and radiation. According to Einstein's theory of relativity, light from a very distant bright source bends around a massive object, e.g., a cluster of galaxies, between the source object and the observer. It follows from this principle that the dark matter in cosmic giants like galaxy clusters alters the apparent shape and position of distant galaxies. Lead author Okabe enthused, "The Subaru Telescope is a fantastic instrument for gravitational lensing measurements. It allows us to measure very precisely how the dark matter in galaxy clusters distorts light from distant galaxies and gauge tiny changes in the appearance of a huge number of faint galaxies."

CDM theory describes how dark matter in galaxy clusters changes from its dense center to its lower density edges in two ways. One is a simple measure of the galaxy cluster's mass, the amount of matter that it contains. The other is a concentration parameter, which is a single measurement of the cluster's average density, how compact it is. CDM theory predicts that central regions of galaxy clusters have a low concentration parameter while individual galaxies have a high concentration parameter.

The team combined measurements from observations of fifty of the most massive known galaxy clusters to calculate their concentration parameter. They found that the density of dark matter increases from the edges to the center of the cluster, and that the concentration parameter of galaxy clusters in the near Universe aligns with CDM theory. The averaged mass map (attachment) is remarkably symmetrical with a pronounced mass peak. The mass density distribution for individual clusters shows a wide range of densities. Past research based on a small number of clusters found that they had large concentration parameters and did not conform to CDM theory. Measurement of the average concentration parameter from a large number of clusters yielded a different result, which supports CDM theory. Okabe commented on the team's findings, based on a larger sample of galaxy clusters: "This is a very satisfying result, which is based on a very careful analysis of the best available data".

What does the future hold for the team's continued research on dark matter? Smith noted, "We don't stop here. For example, we can improve our work by measuring dark matter density on even smaller scales, right in the center of these galaxy clusters. Additional measurements on smaller scales will help us to learn more about dark matter in the future."

Team member, Professor Masahiro Takada from the Kavli Institute for the Physics and Mathematics of the Universe, Japan is also excited about the future: "Combining lensing observations of many galaxy clusters into a single measurement like this is a very powerful technique. Taiwanese and Japanese astronomers are preparing to use Subaru Telescope's new Hyper Suprime-Cam (HSC) to conduct one of the biggest surveys of galaxies in human history. Our new results are a beautiful confirmation of our plan to use HSC for gravitational lensing studies."

The full article entitled "LoCuSS: The Mass Density Profile of Massive Galaxy Clusters at z=0.2" is available at the *Astrophysical Journal Letters* website at: http://iopscience.iop.org/2041-8205/769/2/L35/pdf/2041-8205_769_2_L35.pdf

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